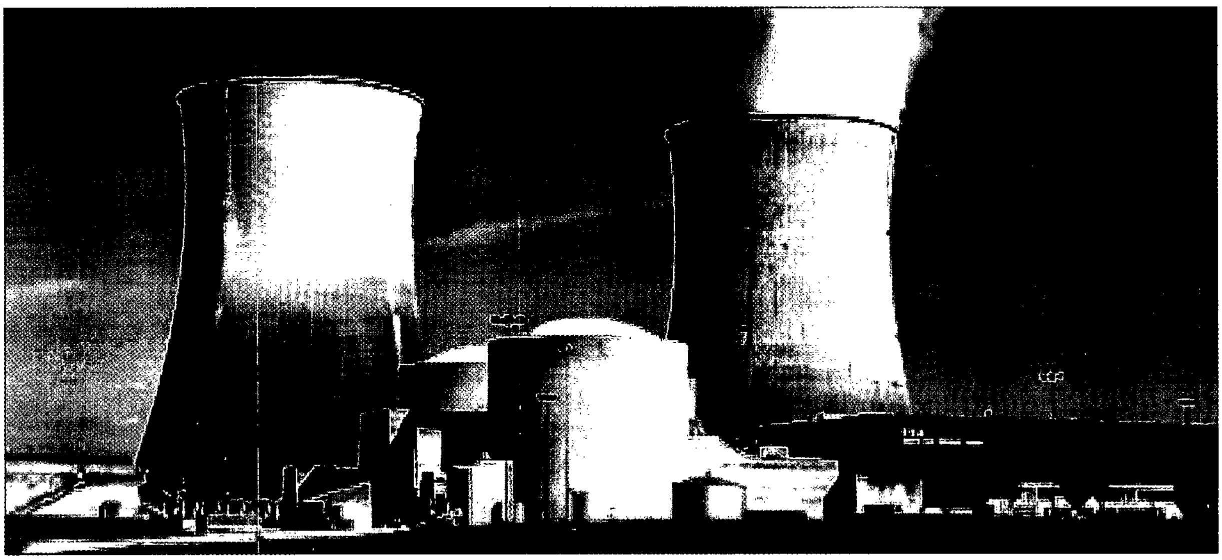
ENCLOSURE 1

HYDROTHERMAL EFFECTS ON THE ICHTHYOPLANKTON FROM THE WATTS BAR NUCLEAR PLANT SUPPLEMENTAL CONDENSER COOLING WATER OUTFALL IN UPPER CHICKAMAUGA RESERVOIR

Hydrothermal Effects on the Ichthyoplankton from the Watts Bar Nuclear Plant Supplemental Condenser Cooling Water Outfall in Upper Chickamauga Reservoir



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INTRODUCTION

The National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for Watts Bar Nuclear Plant (WBN) identifies the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) System as Outfall 113. The permit states that when there is no flow released from Watts Bar Hydroelectric Dam (WBH), the effluent from Outfall 113 shall be regulated based on a Passive Mixing Zone (PMZ) extending in the river from bank-to-bank and 1,000 feet downstream from the outfall.

Current operation of WBN Unit One utilizes the SCCW system through constant gravity flow from above WBH. Completion and operation of Unit 2 will not significantly alter or increase the thermal effluent from the SCCW outfall.

Two hydrothermal surveys and one flow pattern survey were conducted in the vicinity of WBN during May and August 2010, when there were no releases from upstream WBH through generators or spillways to characterize attributes of the SCCW thermal plume. Water temperatures were recorded upstream and downstream of the SCCW discharge during this test to characterize the thermal aspects of the plume. Drogues, devices designed to drift with surface currents, were deployed at and near the SCCW outfall to track flow patterns and compare flow paths during normal and no generation from Watts Bar Dam.

The thermal plume was tracked and measured in conjunction with day and night ichthyoplankton sampling to describe temporal and spatial distribution of fish eggs and larvae and exposure rates to the thermal plume. This report presents the results of these surveys in relation to potential effects to ichthyoplankton from exposure to the thermal plume with no river flows being created by generation at the dam and constant SCCW discharge.

METHODS

The May survey was designed to coincide with the period of expected peak abundance of fish eggs and larvae in this area. Accordingly, tests were conducted during the day on May 19, 2010 and during the night of May 20-21. The August survey was in turn scheduled to coincide with near maximum ambient water temperatures when most fish eggs have hatched and larvae matured and no longer drifting in the water column.

Characterization of the SCCW Thermal Plume

Flow Path Tracking with Drogues

Multiple drogue releases were necessary to capture the desired data. This is because drogues must move with the current in order to gather the desired data and they eventually leave the area of interest making it necessary to gather and release them repeatedly, depending on the duration of the test. In this case, daytime and nighttime sessions each required four releases to capture the flow patterns over the low-flow periods. The drogues were equipped with Global Positioning Systems (GPS) to record and determine their position. These tests are considered representative of flow patterns that develop from WBH releases while the SCCW discharge remains constant.

River Temperature Collection with HOBOs

The hydrothermal surveys also included the collection of temperature data at twelve temporary monitoring stations using HOBO water temperature sensors deployed across the river channel from the SCCW discharge, upstream from the SCCW discharge, and across the downstream edge of the PMZ during periods of no release from WBH (Appendix A). Locations of HOBO stations are depicted in Figure 1. HOBO sensors were positioned at depths of 0.5, 3, 5, and 7 feet below the water surface and have an accuracy of about ±0.4°F and resolution of about 0.04°F. The HOBO devices include an internal data acquisition unit and were programmed to collect measurements once per minute. All the temperature probes used in the survey were calibrated by a quality program with equipment traceable to the National Institute of Standards and Technology (NIST). The temporary monitoring stations were deployed on August 18, several hours before the beginning of the survey, and were retrieved at the end of the survey. A GPS device was used to position the stations along the downstream edge of the PMZ. Detailed hydrothermal survey methods and explanation of the mixing zone boundaries can be found in Ruth and Hopping, 2010.

Ichthyoplankton Sampling

Abundance, distribution and taxonomic composition of ichthyoplankton was estimated during the two hydrothermal surveys (May 19-21 and August 25-27) by collecting samples at a transect below Watts Bar Dam (Figure 2). To estimate density and composition of fish eggs and larvae entrained at the SCCW intake above the dam, four samples (two each during day and night) were collected weekly immediately in front of the SCCW intake.

Ichthyoplankton samples below the SCCW outfall were collected during both day and night along a transect at TRM 528.0. One tow-net sample, approximately ten-minutes long was collected near each shoreline, at 40 and 60% of the distance across the transect and one bottom-drag sample towed near the bottom at mid-channel. Detailed ichthyoplankton sampling methodology is presented in TVA, 2010.

Ichthyoplankton data from samples collected at both locations (above and below dam) during the week prior to and the week after the hydrothermal survey were included in the analysis for comparison with normal generation conditions. A transect was also established at TRM 530.2 to characterize ichthyoplankton densities upstream of the dam using the same methods as the downstream transect. Data from the weeks prior to and following the surveys are included to determine if the May and August surveys represented the seasonal larval density and the seasonal maximum temperatures. Weekly sampling at these sites was initiated in March 2010 as part of preoperational monitoring for WBN Unit 2.

Larval fish (and egg) exposure rates (time exposed to increased temperatures) were compared to thermal limit data listed in Yoder et al., 2006 to evaluate species potentially affected. Upper incipient lethal temperature limits for each taxon collected were used to determine if these temperatures were exceeded.

It should be noted that densities of fish eggs and larvae from samples collected from five stations across the transect at TRM 528.0 are calculated from each sample during both day and night on the sample dates. At the SCCW intake above Watts Bar Dam, each density represents one sample (composited from two) each during both day and night. Therefore, samples frequently contained low actual numbers (occasionally only one individual) of eggs and larvae. These densities are presented primarily to compare taxonomic composition collected at the SCCW intake with that occurring at the downstream transect and to estimate densities of eggs and larvae which might be exposed to the SCCW outfall temperatures under low flow conditions.

RESULTS

Characterization of the SCCW Thermal Plume

Flow Path Tracking with Drogues

The first release of the daytime test began just after 6:00 AM (Figures 3 and 4), while Watts Bar Dam was still releasing water for generation. This discharge ceased at 7:05 AM. All drogues except the unit released closest to the SCCW discharge moved downstream rapidly (speed is shown by the length of the color bands, which represent distance traveled in 7.5 minutes) until the discharge was shut off. The SCCW drogue appeared to stay near the shoreline. All drogues slowed their drift immediately after generation ceased. They then were influenced by a sloshing effect of the reservoir caused by the rapid shutoff of Watts Bar Dam, some traveling upstream. After generation was stopped, the drogue released upstream of the SCCW and closest to the left descending bank was caught in an eddy that carried it upstream into the navigation lock.

The second array of drogues was released at 8:00 AM (Figure 5), 55 minutes after dam shutoff. During this period, most of the drogues track upstream. Water flow during this time interval was influenced by upstream slosh, along with turbine leakage from the dam and SCCW discharge. Though the flow rates of the turbine leakage and the SCCW discharge were similar (approximately 250 cubic feet per second [cfs] turbine leakage and an average of 284 cfs SCCW discharge), the turbine leakage was cooler and stayed near the bottom, while the SCCW discharge was warmer and spread out over the top of the water column. The SCCW discharge influenced drogue paths more since they tracked surface flows. The combination of these factors explained the tendency of the drogues to move upstream with slosh and/or away from the SCCW discharge as it spread out over the surface of the slowly moving river. The drogue unit released upstream of the SCCW discharge was pushed slowly downstream by leakage through the turbines at the dam.

By the time of the third release (Figure 6), the drogues released near the SCCW were carried across the river and moved downstream primarily along the opposite shoreline. They were joined in that cross-river flow by drogues released upstream of the SCCW.

The fourth release (2:00 PM, Figure 7) began by following the pattern of the third release with slow downstream flow modified by cross-channel flow created by the SCCW discharge. Near the end of the time period, dam releases increased and downstream flow accelerated making the SCCW discharge and resulting thermal stratification a much smaller influence on flow patterns.

The nighttime test began just after 8:00 PM on May 20 (Figures 8 and 9). As in the daytime test, water was released for generation at the beginning of the test and ceased partway through the first drogue release. For the first release, drogue paths were all downstream. All but one of the drogues had moved out of the test area by the time releases from WBH ceased.

During the second drogue release at midnight of May 21 (Figure 10), three hours after releases from WBH ceased, the drogues moved away from the SCCW discharge. Since this discharge was warmer than it was at this point in the daytime test, it is likely that the warm SCCW discharge spreading across the surface of the nearly stationary river was the principal determinant of surface flow patterns. Leakage from the turbines appeared to influence travel paths of those drogues released closest to the dam.

The third drogue release began at 1:52 AM (Figure 11). The SCCW discharge appeared to continue to be the primary influence on surface flow patterns and drogue paths, with all drogues moving away from this discharge point.

Drogue paths continued to be primarily determined by the SCCW discharge for the first part of the fourth drogue release at 3:30 AM (Figure 12). Dam discharge began increasing at 5:00 AM, whereupon all drogues began travelling downstream with the increased turbine flow and increased vertical mixing.

River Temperature Collection with HOBOs

Ambient river temperature released from Watts Bar Dam remained constant between 69° and 70°F during the May day and nighttime tests (Table 1). The ambient river temperature releases from Watts Bar Dam were warmer in August, beginning the tests at 79° to 80°F. River temperature decreased slightly after dam discharge was stopped. Cooler water from turbine leakage originating deeper in the reservoir reduces ambient temperatures after the dam discharge stops.

After the dam discharge ceased, warm water from the SCCW discharge was detected at the upstream stations, mostly near the surface. Maximum surface temperature in the upstream transect was 73°F in the May test, about 4°F above ambient. In the August daytime test, the upstream surface warmed to 81.5°F; the nighttime test showed minimal warming above ambient river temperature across the upstream stations.

HO-1, the station closest to the SCCW discharge, saw the highest surface temperatures in all tests and the highest bottom temperature in three of the four tests. May surface temperatures did not exceed 76°F and bottom temperatures did not exceed 72°F. August surface temperatures remained under 83°F while bottom temperatures briefly exceeded 81°F.

After dam shutoff, all PMZ stations became warmer on the surface while staying at or near ambient at the bottom. PMZ stations stayed cooler than HO-1 except for H-PMZ1 in the August daytime test. Maximum temperature difference between the PMZ stations and ambient river temperature occurred just after dam discharge resumed, when a pulse of cooler water was seen at the upstream ambient sensor and before this cooler water reached the PMZ transect. Maximum difference between ambient and surface temperature reached 5°F during the May night test, 5.34°F during the May day test, and 5.36°F during the August day test. Temperature differences were smaller at greater depth and during the August night test.

Ichthyoplankton Sampling

Results of ichthyoplankton sampling conducted above and below Watts Bar Dam during May and August 2010 hydrothermal surveys are presented below. A list of larval fish and eggs by family and common name collected near WBN during May and August are listed in Table 2. . Identical families of both eggs and larvae were also represented in samples collected above Watts Bar Dam during the May and August surveys (Table 3).

May Survey

Tables 3 through 10 include data from the week of the survey and from corresponding samples collected during normal turbine generation/flow on May 11-12 and May 25-27, the weeks before and after the hydrothermal survey for comparison. All density values are number of eggs or larvae per 1000 m^3 with actual numbers of eggs and larvae collected in parentheses.

Above dam control transect (TRM 530.2) – Samples collected during May 19-21 from five stations across the transect above Watts Bar Dam were combined to provide total densities for fish eggs and larvae in the forebay upstream of the SCCW intake. Only one freshwater drum egg was collected in a night sample. Clupeid larvae dominated the samples with densities of 179 (70) and 1282 (495) per 1000m^3 during day and night, respectively. Centrarchid (sunfish) larvae were next in abundance with densities of 26 (10) and 47 (18) during day and night, respectively. Larval cyprinids (minnows) were less abundant at 3 (1) and 13 (5) per 1000 m^3 during day and night, respectively, as well as atherinopsids (silversides) at 3 (1) and 26 (10) per 1000 m^3. Larval *Moronidae* (white and yellow bass) and *Sciaenidae* (freshwater drum) were collected in night samples only at densities of 41 (16) and 10 (4) per 1000 m^3, respectively (Table 3).

SCCW Intake – Samples collected at the SCCW intake during the week of May 19-21 contained freshwater drum eggs and larvae representing four families. Drum eggs were collected in the night samples only at a density of 18 per 1000 m^3 (3 eggs). Clupeid larvae dominated the samples with densities of 253 (39 larvae) and 871 (144) per 1000 m^3 during the day and night samples, respectively. Centrarchid larvae were next in abundance with densities of 32 (5) and 18 (3) per 1000 m^3 during day and night samples, respectively. Two other families (*Cyprinidae* and *Sciaenidae*) were collected in night samples only at densities of 6 (1) each per 1000 m^3 (Table 4).

Below dam (TRM 528.0) – Samples collected from five stations across the downstream transect during May 19-21 are discussed below.

Right descending bank – Freshwater drum eggs were collected at 73 (6) per 1000 m^3 in the night sample only. Larval clupeid densities were 40 (3) and 813 (67) per 1000 m^3 during day and night, respectively. Centrarchids densities were 13 (1) and 36 (3) per 1000 m^3 during day and night, respectively. One specimen each (12 per 1000 m^3) of *Atherinopsidae* (silversides) and *Moronidae* (white and yellow bass) was collected during the night sample only (Table 5).

40% of reservoir width from right descending bank – No fish eggs were collected at this station. Larval clupeid densities were 180 (13) and 1,158 (91) per 1000 m^3 during day and night, respectively. Densities of freshwater drum larvae were collected at 25 (2) per 1000 m^3 during night only. Centrarchid densities were 14 (1) per 1000 m^3 and were collected during the day sample only, while *Moronidae* densities were 14 (1) per 1000 m^3 and were collected during night only. Freshwater drum densities were 25 (2) per 1000 m^3 during night sample only. Total larval density (1,390 per 1000 m^3) at this station was higher during the survey week than either the preceding or following week (Table 6).

60% of reservoir width from right descending bank – Freshwater drum eggs were collected at 38 (3) per 1000 m^3 during night only. Densities of clupeid larvae were 391 (30) and 1593 (127) per 1000 m^3 during day and night, respectively. Silverside densities were 13 (1) per 1000 m^3 during both day and night. The density of centrarchid larvae was 13 (1) per 1000 m^3 during day only. One each (13 per 1000 m^3) *Percidae* (darter) and *Sciaenidae* (drum) larva was collected during night only. Total larval density (2,137 per 1000 m^3) at this station was higher during the survey week than either the preceding or following week (Table 7).

Left descending bank – No fish eggs were collected at this station during the survey week. Clupeid larvae were collected at 526 (41) and 3,066 (244) per 1000 m^3; *Moronidae* densities were 26 (2) and 38 (3) per 1000 m^3 each during day and night, respectively. *Atherinopsidae* densities was 13 (1) per 1000 m^3 during both day and night samples. *Centrarchidae* density was 25 (2) per 1000 m^3 during night sample only. Total larval density at this station (3,707 per 1000 m^3) during the survey week was higher than either the preceding or following week (Table 8).

Bottom sample mid-channel – The density of freshwater drum eggs was 12 (1) per 1000 m^3 during night only. Clupeid larvae were collected at densities of 236 (17) and 347 (27) per 1000 m^3; *Centrarchidae* larvae at 14 (1) and 26 (2) per 1000 m^3; and *Moronidae* larvae at 14 (1) and 13 (1) per 1000 m^3, each during day and night, respectively. Total larval density at this station (728 per 1000 m^3) during the survey week was higher than either the preceding or following week (Table 9).

Below Dam (TRM 528.0; five stations combined) – During the survey week of May 19-21, 114 total larvae (density of 306 per 1000 m^3) were collected during the day samples at the five stations below the dam, while 594 total larvae (1,819 per 1000 m^3) and 10 freshwater drum eggs (31 per 1000 m^3) were collected during the night sample. There were 85 (216 per 1000 m^3) and 357 (954 per 1000 m^3) total larvae collected during the day and night samples, respectively, in the week prior to the survey week. One hundred total larvae (259 per 1000 m^3) and 3 eggs (8 per 1000 m^3) were collected during the week following (May 25-27) in the day sample, while 355 (866 per 1000 m^3) total larvae and 81 freshwater drum eggs (197 per 1000 m^3) were collected during the night sample. The dominant taxon collected in the three weeks in May during both day and night samples was clupeids. Peak density at all stations combined below the dam was observed during the survey week of May 19-21; total density during the survey week (2,125 per 1000 m^3) was almost double that of the weeks prior to (1,161 per 1000 m^3) and following (1,125 per 1000 m^3) (Table 10).

August Survey

Tables 11 through 18 include data from the week of the survey and from corresponding samples collected during normal turbine generation/flow on August 17-18 and August 30-31, the weeks before and after the hydrothermal survey, for comparison. Most fish species have completed spawning by late August and most young fish have developed beyond the larval stage. The hydrothermal survey was conducted during this period to determine the maximum or near maximum temperatures to which any larval or juvenile fish would be exposed in the SCCW thermal plume under low flow conditions.

Above dam control transect (TRM 530.2) – Samples collected during August 25-27 from five stations combined across the upstream control transect contained no fish eggs and only eleven fish larvae (or juveniles). Densities of centrarchids were 10 (4) and 16 (6) per 1000 m^3 during day and night samples, respectively, and one clupeid was collected in the night samples for a density of 3 per 1000 m^3 (Table 9). During the previous week (August 17-18) under normal flow conditions, the day sample contained a density of 13 (5) per 1000 m^3. The night sample densities included silversides 3(1) per 1000 m^3, centrarchids 81 (32), clupeids 25 (10) and cyprinids 8 (3). Samples collected August 30-31 contained one centrarchid during both day and night samples for a density of 3 per 1000 m^3 and two clupeids (5 per 1000 m^3) in the night sample (Table 11).

SCCW Intake – No eggs and only one centrarchid larva was collected in the day samples during the August 25-27 survey (Table 10). No eggs or larvae were collected in the night sample. Samples collected August 17-18 contained only centrarchids with a density of 102 (15) in the day sample and 13 (2) in night sample. August 30-31 samples collected one centrarchid during both day and night samples for a density of 7 per 1000 m^3 each (Table 12).

Below dam (TRM 528.0) – Samples collected from five stations across the downstream transect during August 25-27 are discussed below.

Right descending bank – No fish eggs or larvae were collected during the week prior to (August 17-18) or during August 25-27 from this station sampled both day and night. During the following week (August 30-31), one larval fish (*Centrarchidae*; density of 12 per 1000 m^3) was collected during the night sample (Table 13).

40% of reservoir width from right descending bank – No fish eggs or larvae were collected during any of the three weeks from this station sampled both day and night (Table 14).

60% of reservoir width from right descending bank – One centrarchid larva (density of 13 per 1000 m^3) was collected during the day sample of August 17-18. No fish eggs or larvae were collected from this station during the weeks of August 25-27 or August 30-31 (Table 15).

Left descending bank – No fish eggs or larvae were collected from this station sampled both day and night during the first (August 17-18) and second (August 25-27) weeks of the study. During the third week one drum egg (density of 12 per 1000 m^3) was collected during the night sample. Two centrarchid larvae (density of 28 per 1000 m^3) were collected from this station during the night sample of the week following that of no generation (August 30-31) (Table 16).

Bottom sample mid-channel – No fish eggs or larvae were collected during any of the three weeks from this station sampled both day and night (Table 17).

Below Dam (TRM 528.0; five stations combined) – No fish eggs or larvae were collected August 25-27 from the five stations sampled both day and night at the transect below the dam at TRM 528.0 (Table 11). The day sample during August 17-18 collected one centrarchid (density of 3 per 1000 m^3). No fish eggs or larvae collected in the night sample. August 30-31 samples collected two centrarchids (8 per 1000 m^3) in the day sample and nothing in the night sample (Table 18).

CONCLUSIONS

Tracking and mapping the SCCW thermal plume with no release from WBH showed that the plume remained near the surface and spread across the river instead of being confined near the right descending bank, as observed under normal releases from WBH. Maximum temperatures recorded during the May and August no-flow surveys were 74.8°F and 82.7°F (both recorded at HOBO station nearest SCCW discharge), respectively. These maximum seasonal temperatures were lower than the Tennessee State Water Quality Criteria for Temperature of 86.9°F (30.5°C) which was developed to provide protection for aquatic resources.

During the May 19-21 survey, densities of larval fish were higher at the downstream transect (all stations combined) than the previous and following weekly samples. This indicated that the May survey was conducted either at or near the period of greatest ichthyoplankton abundance.

During the August survey week with no generation, no fish eggs or larvae were collected in the tailwater transect below the WBN SCCW discharge. This suggests that no ichthyoplankton would have been exposed to the thermal effluent during this period of peak (or near peak) seasonal temperatures.

Based on the taxa found from the ichthyoplankton collected, the thermal tolerance data in Yoder et al. (2006), river temperatures and exposure times measured in the study, there is essentially no risk of thermal damage to ichthyoplankton during no-flow conditions from WBH. This is true for both the high-density ichthyoplankton season (May) and the season with highest river temperatures (August).

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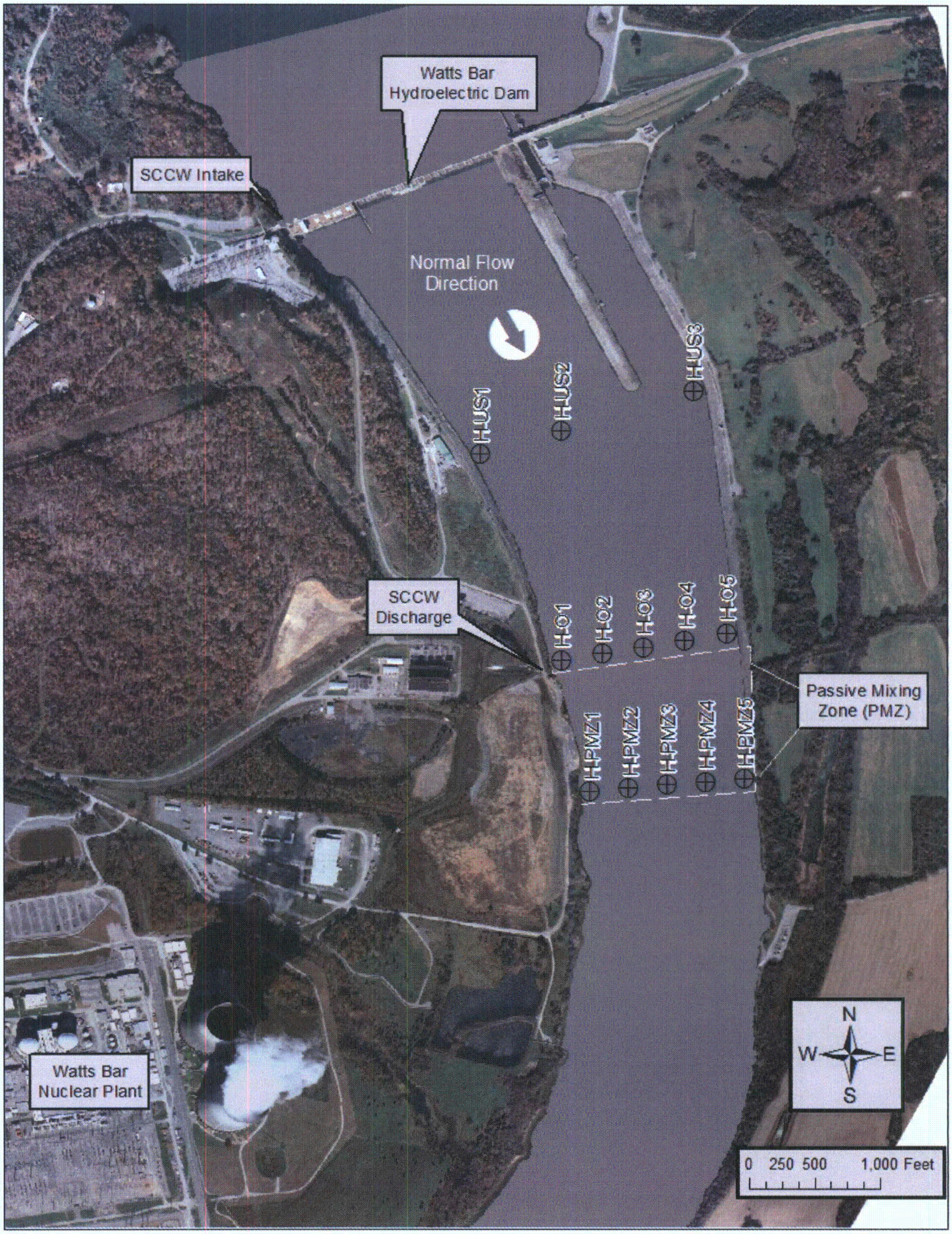

Figure 1. Locations of HOBO temperature recorders along transects across from (H-O1, H-O2, H-O3, H-O4, H-O5), upstream (H-US1, H-US2, H-US3) and downstream (H-PMZ1, H-PMZ2, H-PMZ3, H-PMZ4, H-PMZ5) of the SCCW discharge.

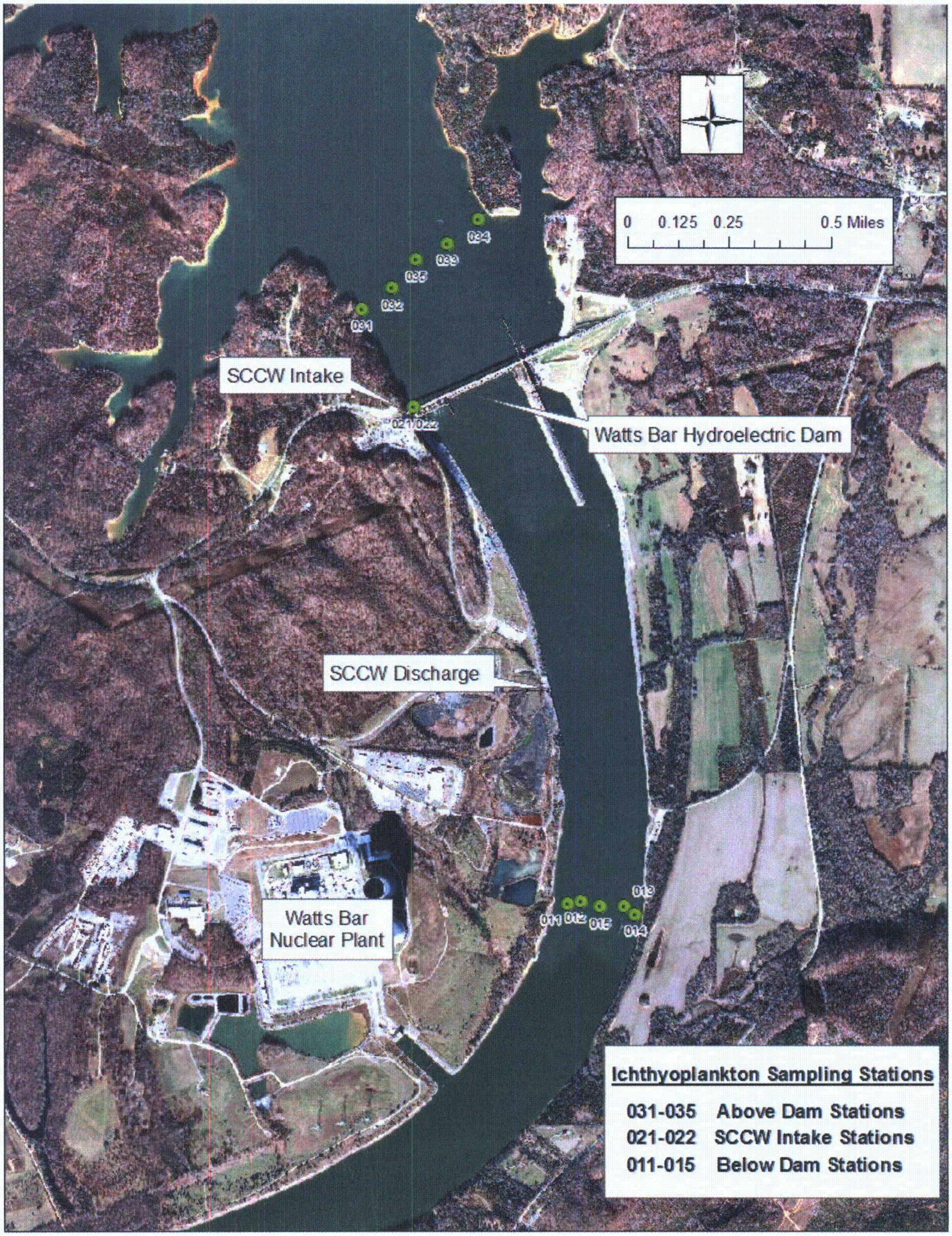

Figure 2. Locations of transects and sampling stations for larval fish and eggs upstream and downstream of Watts Bar Nuclear Plant, Chickamauga Reservoir, Rhea County, TN.

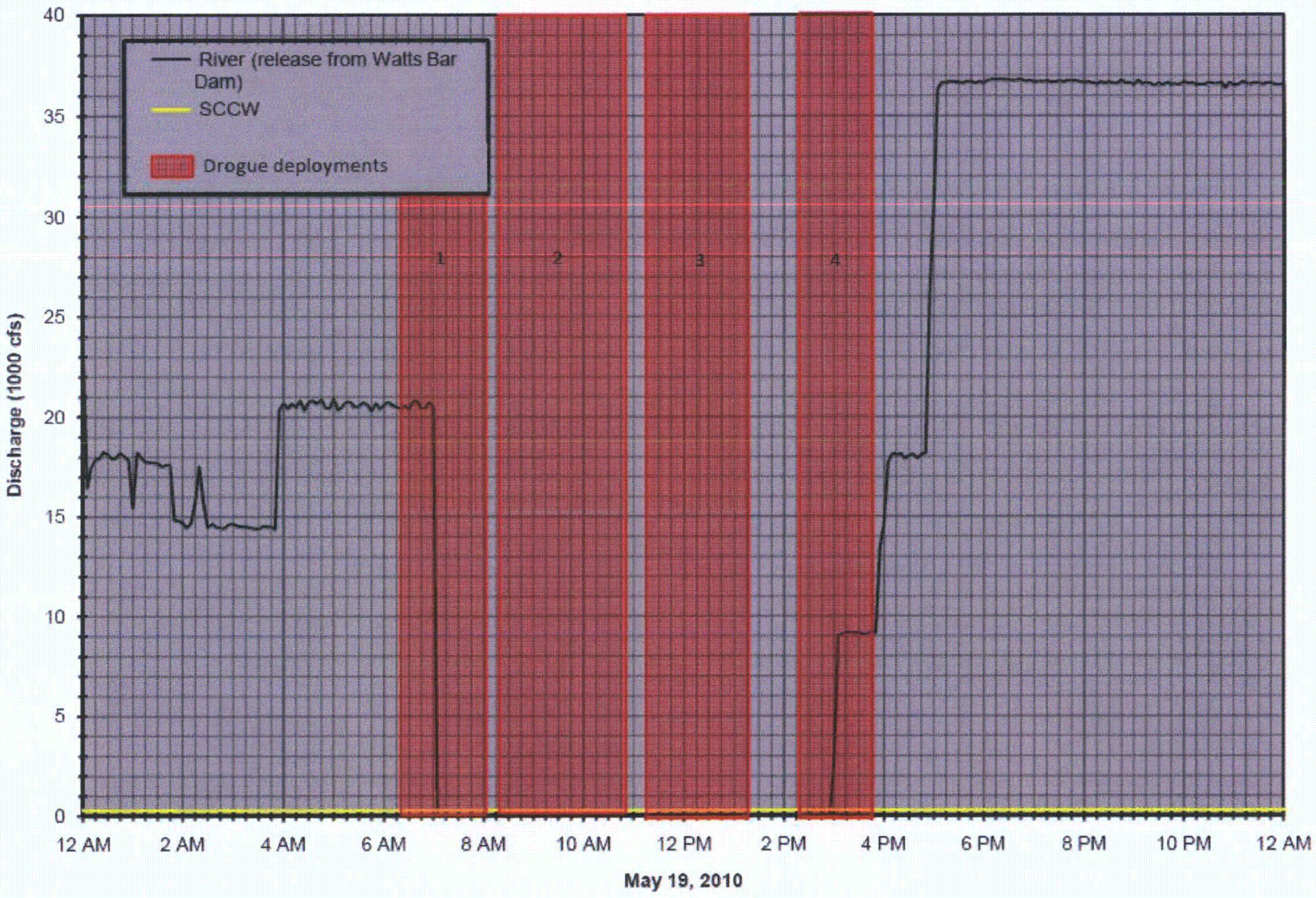

Figure 3. Drogue release times and flow at WBN for daytime test on May 19, 2010.

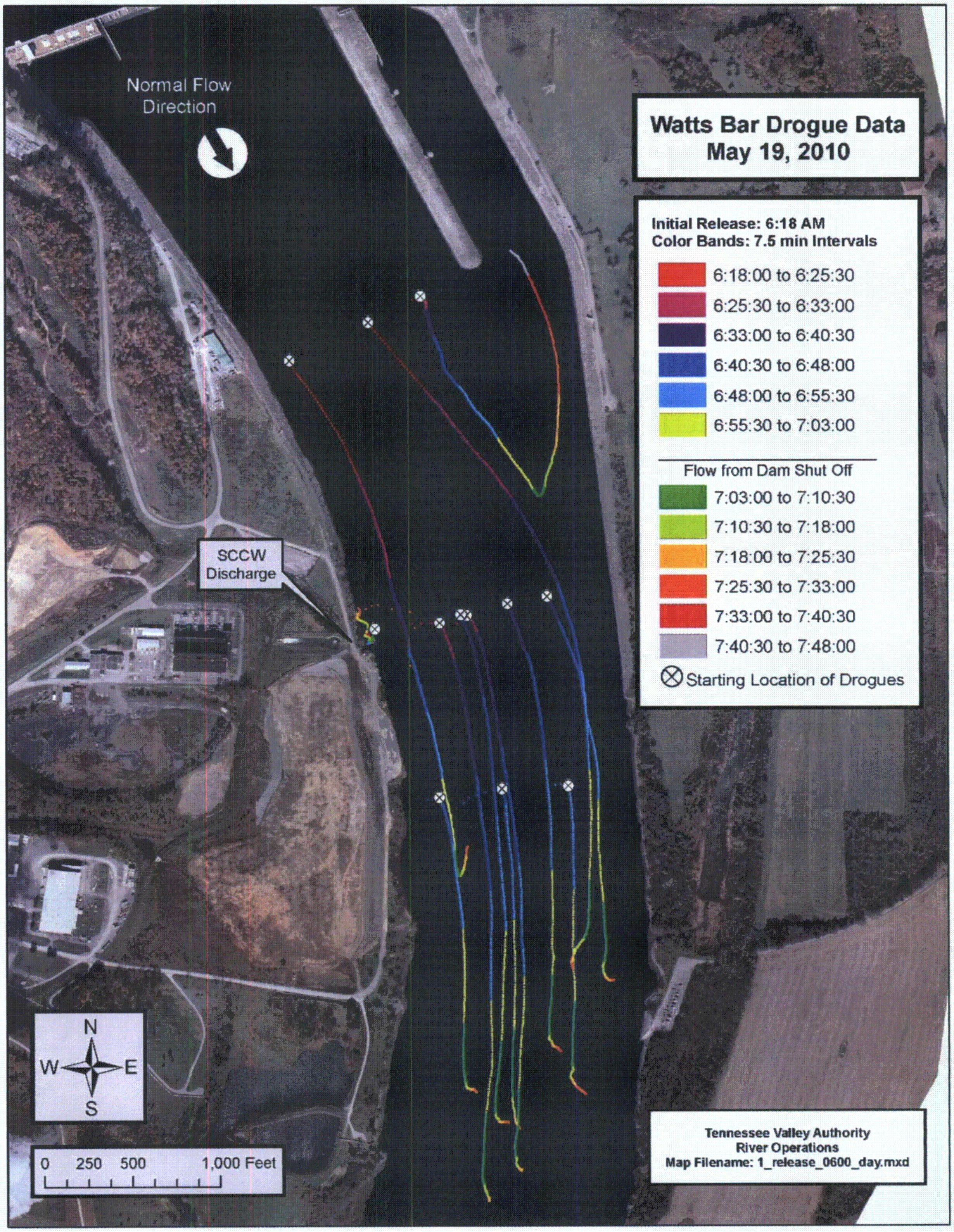

Figure 4. Drogue paths by time at WBN, 6:00 AM to 7:48 AM (first release of daytime test) May 19, 2010.

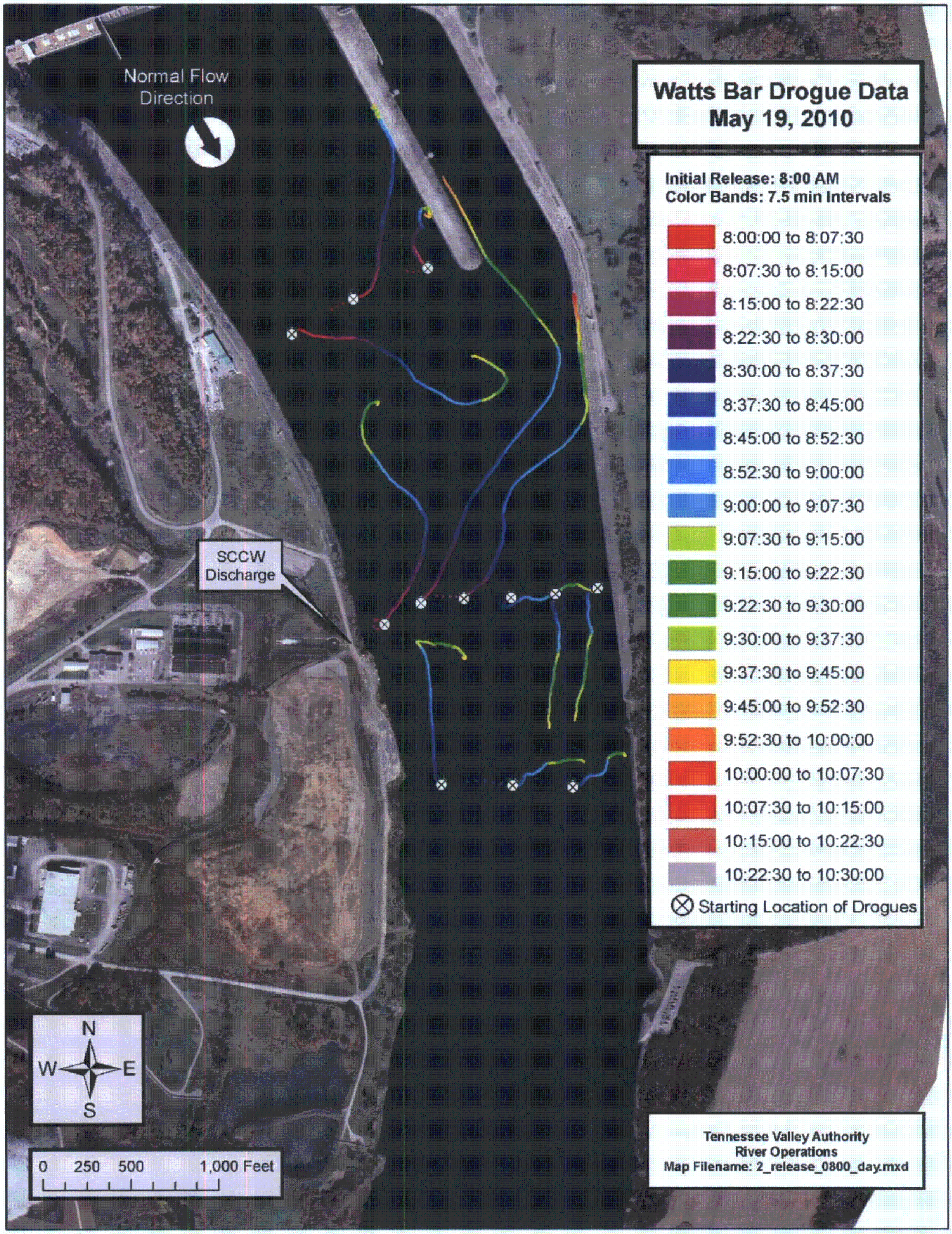

Figure 5. Drogue paths by time at WBN, 8:00 AM to 10:30 AM (second release of daytime test) May 19, 2010.

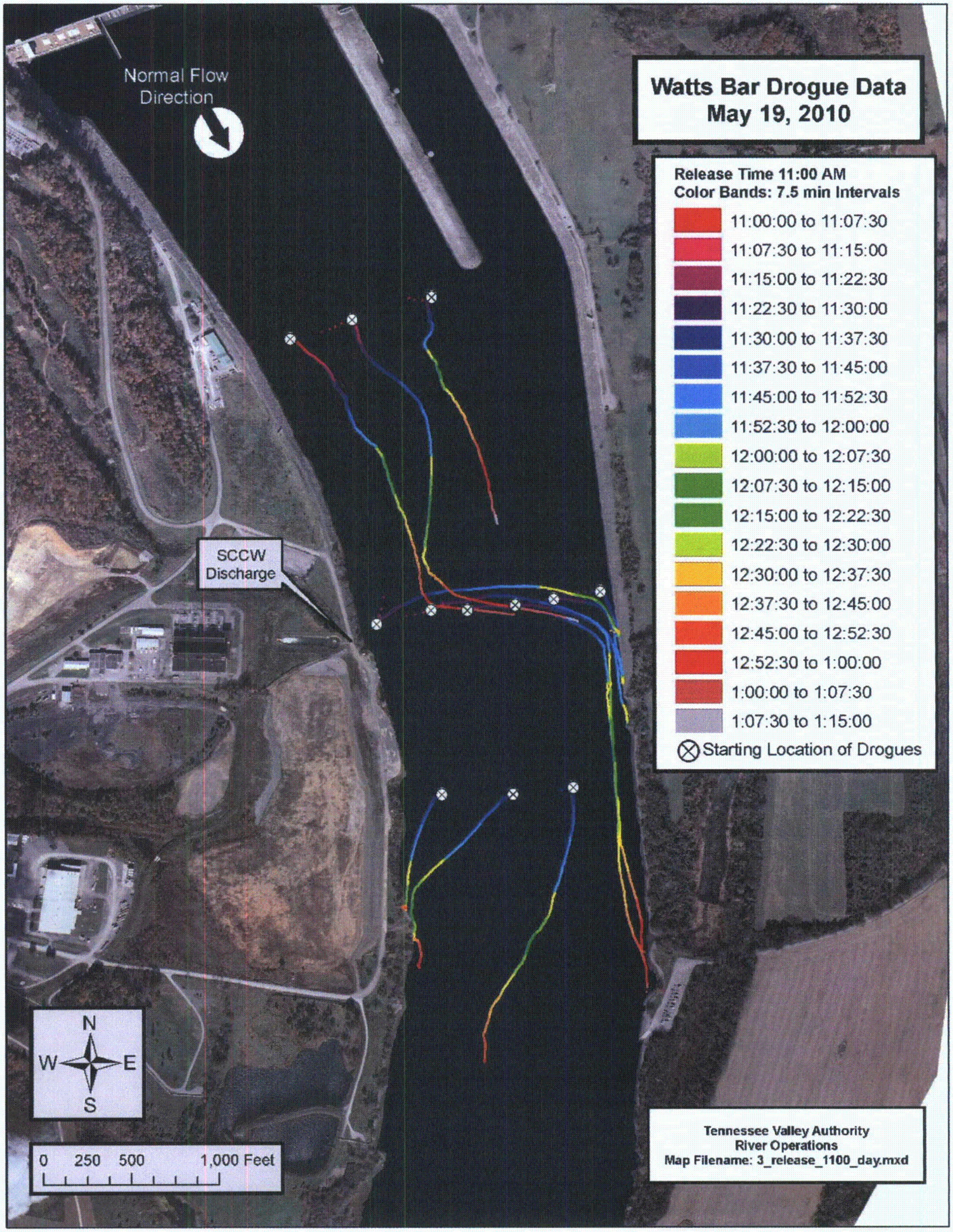

Figure 6. Drogue paths by time at WBN, 11:00 AM to 1:15 PM (third release of daytime test) May 19, 2010.

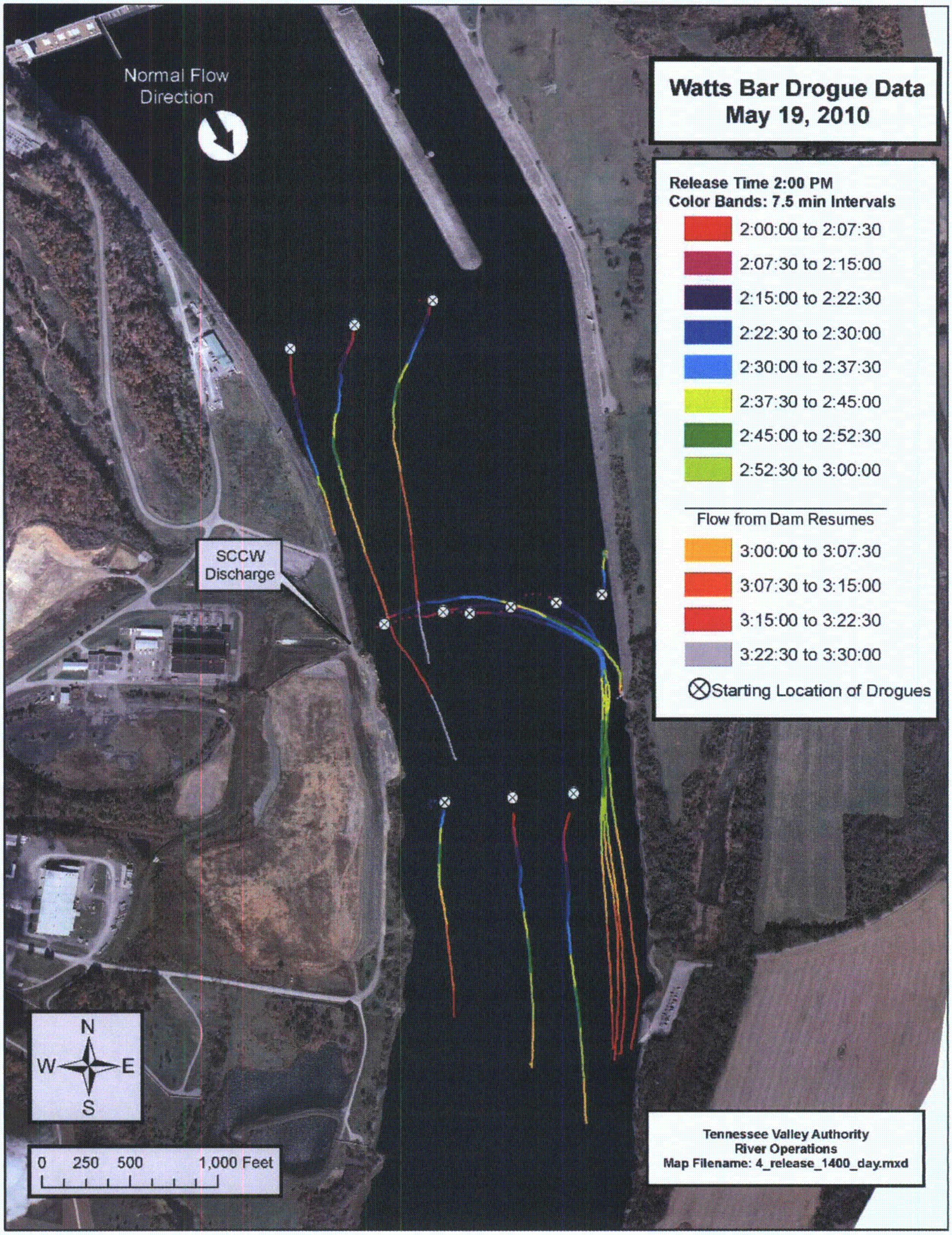

Figure 7. Drogue paths by time at WBN, 2:00 PM to 3:30 PM (fourth and final release of daytime test) May 19, 2010.

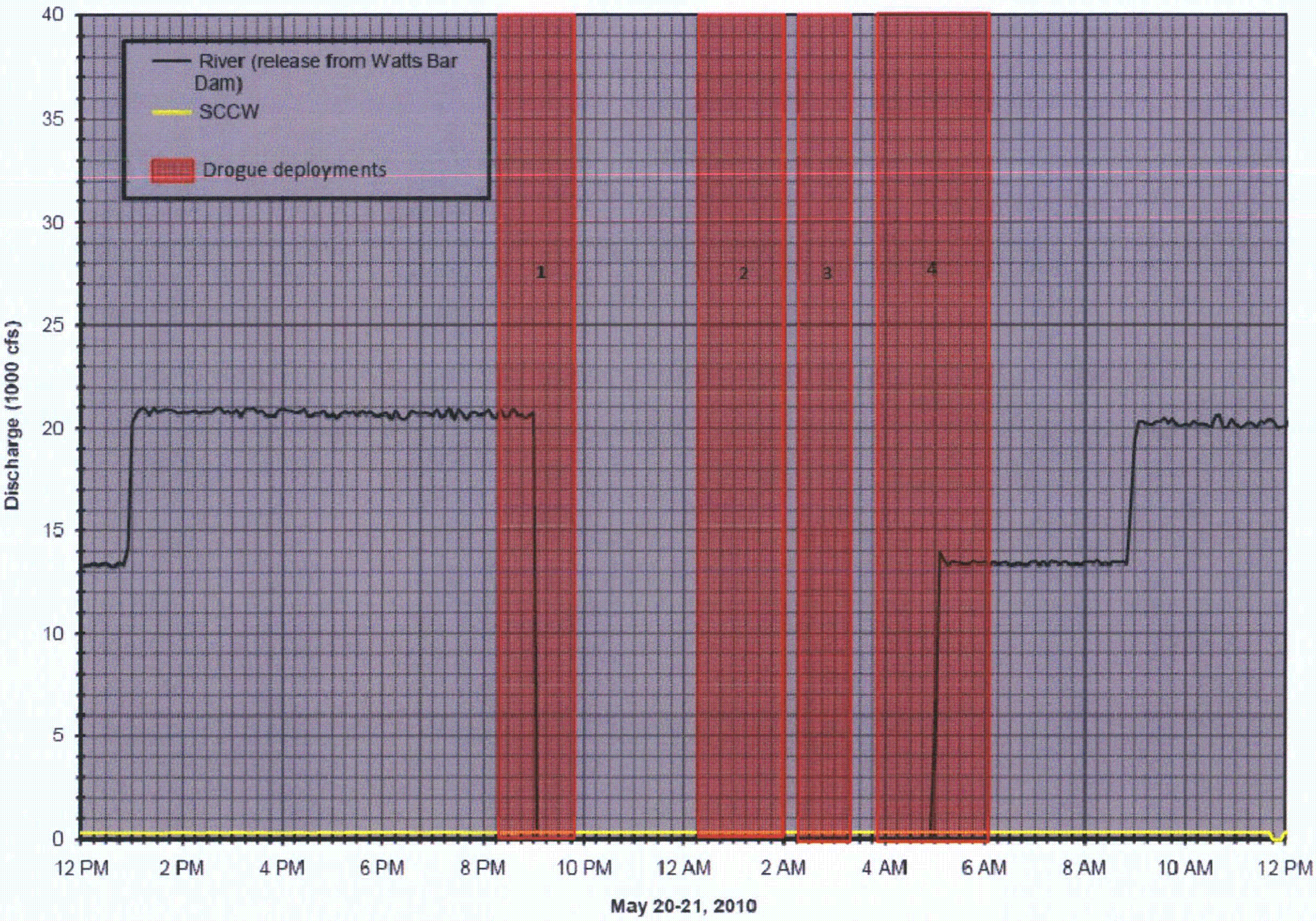

Figure 8. Drogue release times and flow for nighttime test, May 20-21 at WBN.

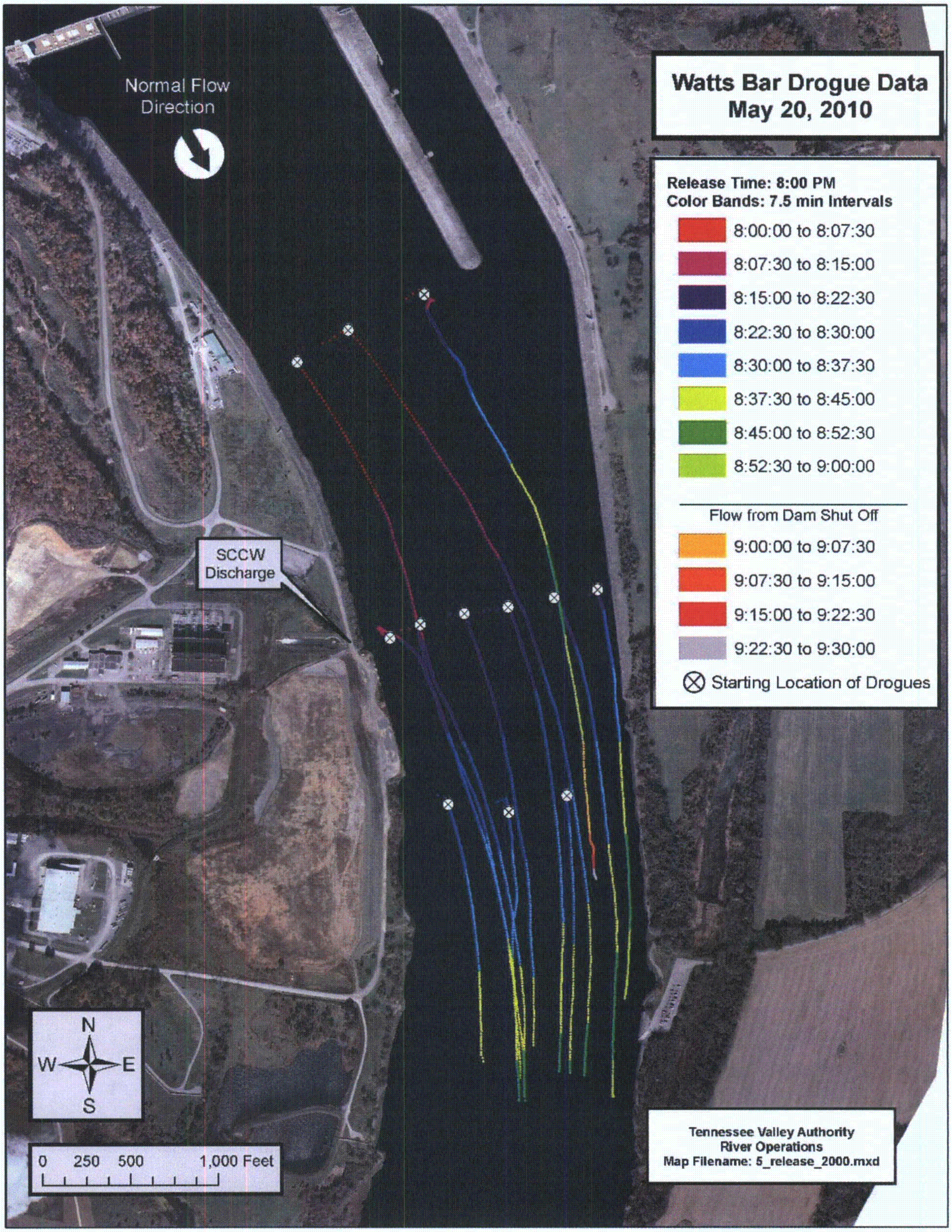

Figure 9. Drogue paths by time at WBN, 8:00 PM to 9:30 PM (first release of nighttime test) May 20, 2010.

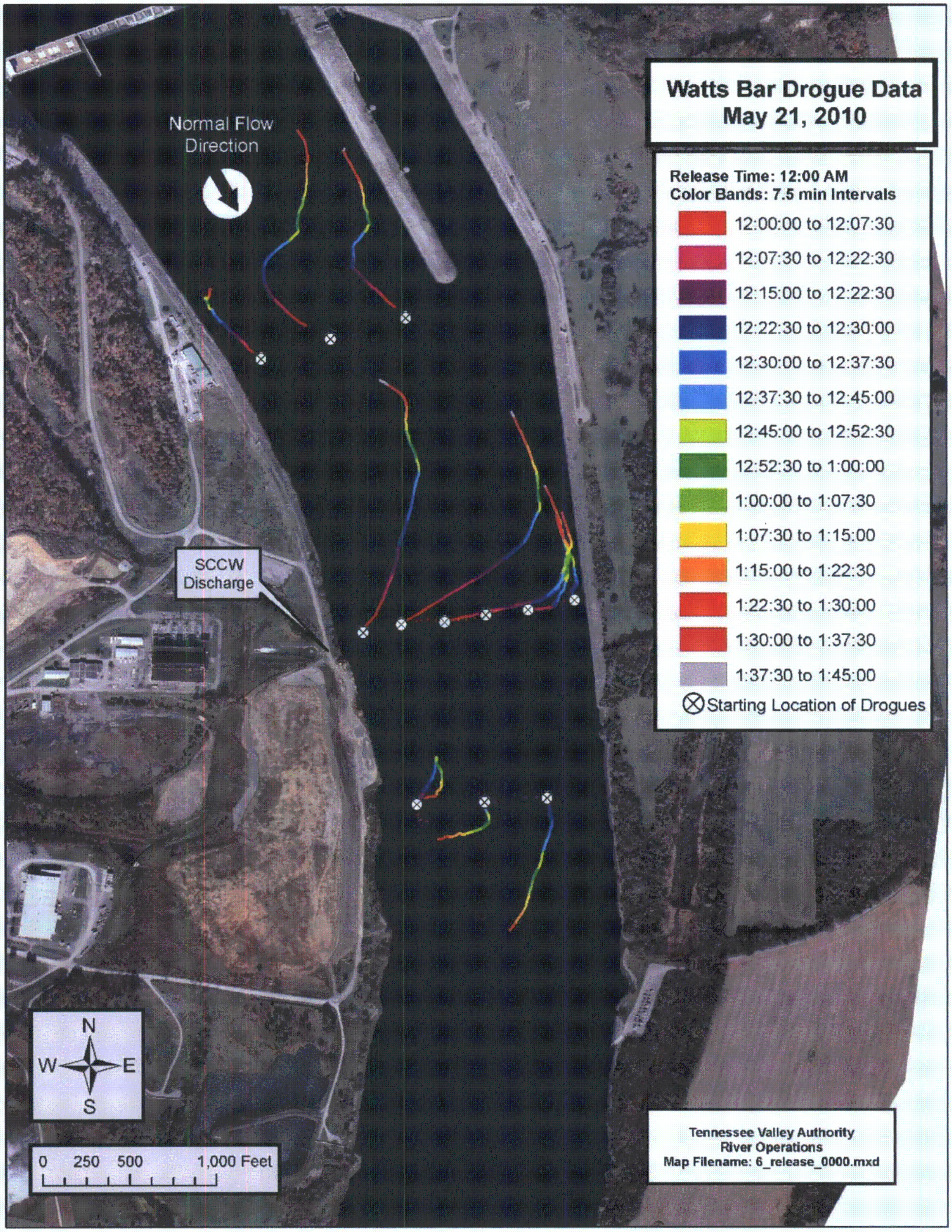

Figure 10. Drogue paths by time at WBN, midnight to 1:45 AM (second release of nighttime test) May 21, 2010.

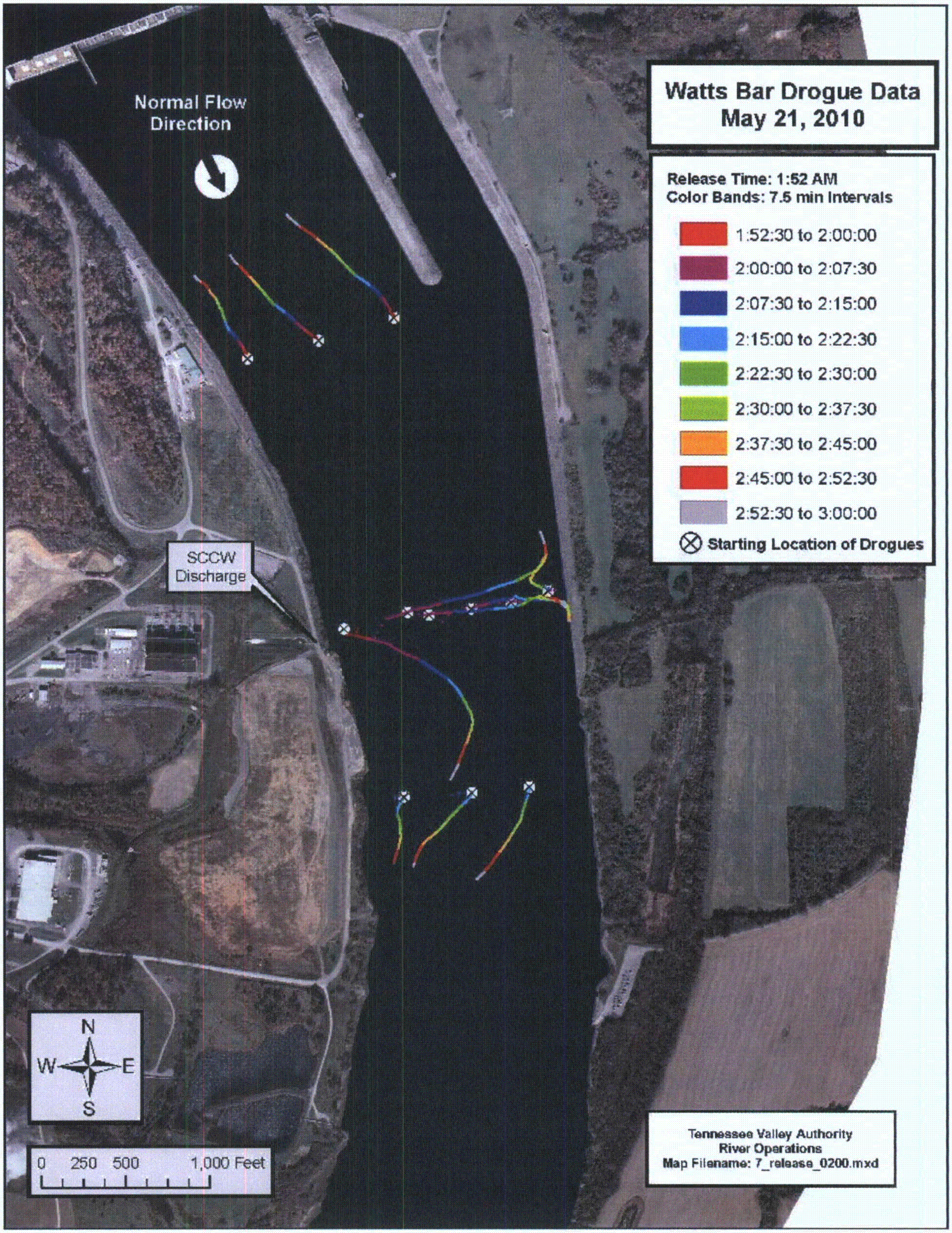

Figure 11. Drogue paths by time at WBN, 1:52 AM to 3:00 AM (third release of nighttime test) May 21, 2010.

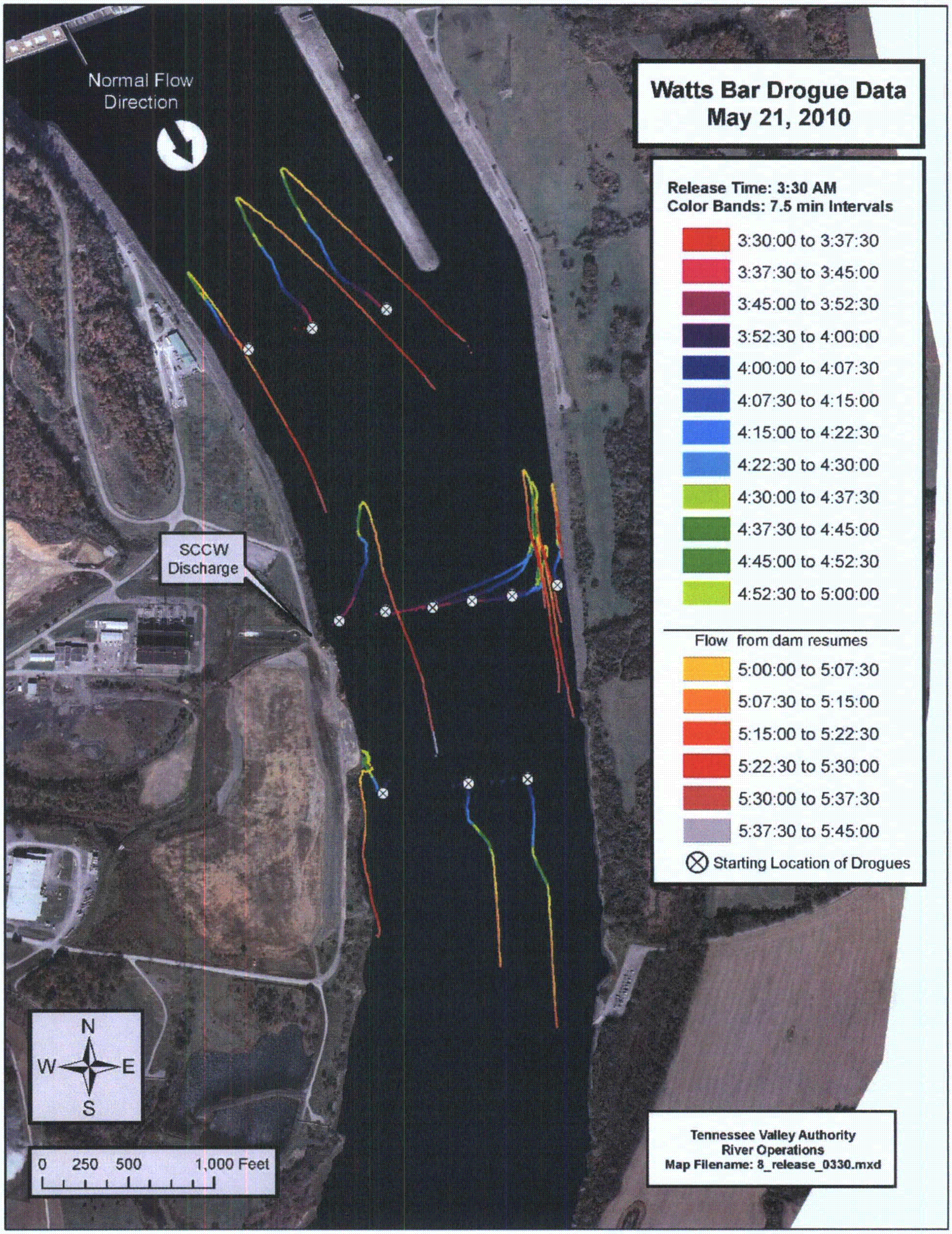

Figure 12. Drogue paths by time at WBN, 3:30 AM to 5:45 AM (fourth and final release of nighttime test) May 21, 2010.

Table 1. Ambient river temperatures, peak river temperatures at surface and bottom of water column, and river temperatures at four locations in the study area (Upstream of the SCCW, SCCW discharge, and the downstream Passive Mixing Zone transects) collected using HOBO temperature stations during day and nighttime tests in May and August 2010 near WBN.

	May		**August**	
Distribution	**Day**	**Night**	**Day**	**Night**
Ambient river temperature	68°-69°F, constant	69°-69.5°F, constant	79°F at dam shutdown, cooling to 76.5°F at restart of dam release	79.5° - 80°F at dam shutdown, cooling to 78°-78.5°F at restart of dam release
SCCW discharge temperature	73.5°F at start of test, warming to 79° at restart of dam	About 80°F through most of test	81°F at start, warming to 82.7° at end of test	82°F at start of test, 81°F at restart of dam release
Peak surface temperature	75°F at HO1	75.5°F at HO1	82.7°F at HO1 and PMZ1	82°F at beginning of test at HO1
Peak bottom temperature	71°F at HO1	72°F at HO1	80.2°F at HO2	81.2°F at HO1
Upstream transect	Surface warms to 73°F peak; little effect deeper	Up to 71°F at surface; some effect lower at US3	Surface warms to 81.5°F; less effect deeper.	Insignificant variation from ambient
Transect at SCCW discharge (HO)	HO1 is warmest; temperature increase dissipates across transect	HO1 is warmest; temperature increase dissipates across transect	HO1 is warmest; temperature increase dissipates across transect	HO1 is warmest but not much increase above ambient. Temperature increase dissipates across transect
Downstream passive mixing zone (PMZ) transect	Surface temperatures at all stations increase to up to 73°; little change at bottom	PMZ2 is warmest, up to 72.5°F at surface. Little or no change at bottom.	Surface temperature at all stations increase to up to 82.5°F	All stations have short 81.5°F peak at beginning; stable at 79°F for rest of test.

Table 2. List of fish and eggs by family collected near Watts Bar Nuclear Plant during May and August ichthyoplankton samples and lowest level of taxonomic resolution for each family.

	Scientific Name	Common Name	Lowest Level of Taxonomic Identification
Eggs			
		Unspecified	Identification to family was not possible. Limiting factors were size, stage of development, and condition (some are damaged).
	Clupeidae	**Shad**	Family.
	Sciaenidae	**Drum**	Species. freshwater drum
Larvae			
	Clupeidae	**Shad**	Family - all larvae < 20 mm TL. Genus or species -larger individuals to *Alosa* spp.- alewife, skipjack, *Dorosoma* spp. - gizzard and threadfin shad.
	Cyprinidae	**Minnows and Carps**	Family -most minnows, shiners, chubs, dace. Genus or species -common carp, golden shiner, and larger individuals to emerald shiner, mimic shiner, *Pimephales* spp.
	Moronidae	**Temperate basses**	Genus -most larval life phases Species - yolk-sac larvae $\geq$ 5 mm TL (striped bass), larger individuals to white, yellow, and striped bass.
	Centrarchidae	**Sunfishes**	Genus - crappie, lepomids (sunfishes), and black bass. Species - larger individuals to largemouth and smallmouth bass.
	Percidae	**Perches**	Family - darters (*Percina* or *Etheostoma*), yellow perch. No sauger were collected. Genus or species -larger individuals to logperch and *Percina* sp.
	Sciaenidae	**Drum**	Species. freshwater drum
	Atherinopsidae	**Silversides**	Family -most larvae (either brook or inland silverside).

Table 3. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation **upstream of Watts Bar Dam** (TRM 530.2) during three weeks in May 2010. Densities were derived using combined numbers of fish eggs and larvae and volumes sampled from all five stations along the reservoir transect upstream of the dam. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Watts Bar Forebay (Combined)	**Week 1 (May 11-12) Normal Generation**		**Week 2 (May 19-21) No Generation**		**Week 3 (May 25-27) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	7 (3)	0	0	0	0	0
Sciaenidae	0	0	0	3 (1)	8 (3)	15 (6)
Total	**7 (3)**	**0**	**0**	**3 (1)**	**8 (3)**	**15 (6)**
Fish Larvae						
Atherinopsidae	3 (1)	0	3 (1)	26 (10)	13 (5)	2 (1)
Centrarchidae	39 (16)	23 (9)	26 (10)	47 (18)	120 (48)	88 (36)
Clupeidae	2188 (889)	358 (139)	179 (70)	1282 (495)	102 (41)	898 (367)
Cyprinidae	0	10 (4)	3 (1)	13 (5)	10 (4)	2 (1)
Moronidae	3 (1)	18 (7)	0	41 (16)	0	29 (12)
Percidae	0	3 (1)	0	0	0	0
Sciaenidae	0	0	0	10 (4)	8 (3)	27 (11)
Total	**2240 (910)**	**412 (160)**	**211 (82)**	**1422 (549)**	**261 (104)**	**1061 (434)**
24-hr Total	**2652 (1070)**		**1633 (631)**		**1322 (538)**	

Table 4. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at the **SCCW intake** (TRM529.9) during three weeks in May 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

SCCW Intake	Week 1 (May 11-12) Normal Generation		Week 2 (May 19-21) No Generation		Week 3 (May 25-27) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	0	0	0	0	0	0
Sciaenidae	0	0	0	18 (3)	0	0
Total	**0**	**0**	**0**	**18 (3)**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	0	21 (3)	32 (5)	18 (3)	79 (12)	63 (10)
Clupeidae	63 (10)	8204 (1181)	253 (39)	871 (144)	996 (152)	1814 (287)
Cyprinidae	0	0	0	6 (1)	0	0
Moronidae	6 (1)	0	0	0	0	6 (1)
Percidae	6 (1)	0	0	0	0	0
Sciaenidae	0	7 (1)	0	6 (1)	13 (2)	0
Total	**75 (12)**	**8232 (1185)**	**285 (44)**	**919 (152)**	**1088 (166)**	**1883 (298)**
24-hr Total	**8307 (1197)**		**1204 (196)**		**2971 (464)**	

Table 5. Densities (number per 1000 m3) of fish eggs and larvae by family collected during normal and no generation at a location **near the right descending bank** of the Tennessee River at TRM 528.0 below Watts Bar Dam during three weeks in May 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Right Bank	**Week 1 (May 11-12) Normal Generation**		**Week 2 (May 19-21) No Generation**		**Week 3 (May 25-27) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	0	0	0	0	0	0
Sciaenidae	0	0	0	73 (6)	0	454 (36)
Total	**0**	**0**	**0**	**73 (6)**	**0**	**454 (36)**
Fish Larvae						
Atherinopsidae	0	0	0	12 (1)	0	0
Centrarchidae	0	13 (1)	13 (1)	36 (3)	128 (10)	76 (6)
Clupeidae	13 (1)	1509 (115)	40 (3)	813 (67)	344 (27)	1552 (123)
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	12 (1)	0	38 (3)
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	13 (1)	88 (7)
Total	**13 (1)**	**1522 (116)**	**53 (4)**	**946 (78)**	**485 (38)**	**2208 (175)**
24-hr Total	**1535 (117)**		**999 (82)**		**2693 (213)**	

Table 6. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **40% of reservoir width from right descending bank** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in May 2010. Numbers in parentheses represent actual numbers of fish eggs or larvae collected.

40% Right Bank	Week 1 (May 11-12) Normal Generation		Week 2 (May 19-21) No Generation		Week 3 (May 25-27) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	143 (12)
Total	**0**	**0**	**0**	**0**	**0**	**143 (12)**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	0	0	14 (1)	0	27 (2)	12 (1)
Clupeidae	99 (8)	714 (55)	180 (13)	1158 (91)	146 (11)	119 (10)
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	13 (1)	0	12 (1)
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	25 (2)	13 (1)	12 (1)
Total	**99 (8)**	**714 (55)**	**194 (14)**	**1196 (94)**	**186 (14)**	**298 (25)**
24-hr Total	**813 (63)**		**1390 (108)**		**484 (39)**	

Table 7. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **60% of reservoir width from right descending bank** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in May 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

60 % Right bank	Week 1 (May 11-12) Normal Generation		Week 2 (May 19-21) No Generation		Week 3 (May 25-27) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	13 (1)	0	0	0	0	0
Sciaenidae	0	0	0	38 (3)	13 (1)	145 (12)
Total	**13 (1)**	**0**	**0**	**38 (3)**	**13 (1)**	**145 (12)**
Fish Larvae						
Atherinopsidae	0	0	13 (1)	13 (1)	0	0
Centrarchidae	0	0	13 (1)	0	51 (4)	24 (2)
Clupeidae	423 (33)	564 (43)	391 (30)	1593 (127)	51 (4)	374 (31)
Cyprinidae	0	0	0	0	0	0
Moronidae	0	13 (1)	0	50 (4)	0	48 (4)
Percidae	0	0	0	13 (1)	0	0
Sciaenidae	0	0	0	13 (1)	25 (2)	36 (3)
Total	**436 (34)**	**577 (44)**	**417 (32)**	**1720 (136)**	**140 (11)**	**627 (52)**
24-hr Total	**1013 (78)**		**2137 (168)**		**767 (63)**	

Table 8. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **near the left descending bank** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in May 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Left bank	**Week 1 (May 11-12) Normal Generation**		**Week 2 (May 19-21) No Generation**		**Week 3 (May 25-27) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	25 (2)	249 (21)
Total	**0**	**0**	**0**	**0**	**25 (2)**	**249 (21)**
Fish Larvae						
Atherinopsidae	0	0	13 (1)	13 (1)	0	0
Centrarchidae	0	0	0	25 (2)	13 (1)	36 (3)
Clupeidae	497 (40)	1715 (131)	526 (41)	3066 (244)	266 (21)	736 (62)
Cyprinidae	0	0	0	0	0	0
Moronidae	12 (1)	0	26 (2)	38 (3)	0	36 (3)
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**509 (41)**	**1715 (131)**	**565 (44)**	**3142 (250)**	**304 (24)**	**1057 (89)**
24-hr Total	**2224 (172)**		**3707 (294)**		**1361 (113)**	

Table 9. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation in samples near **bottom of the main channel** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in May 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Near Bottom	Week 1 (May 11-12) Normal Generation		Week 2 (May 19-21) No Generation		Week 3 (May 25-27) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	0	0	0	0	0	0
Sciaenidae	0	0	0	12 (1)	0	0
Total	**0**	**0**	**0**	**12 (1)**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	13 (1)	0	14 (1)	26 (2)	93 (7)	38 (3)
Clupeidae	0	152 (11)	236 (17)	347 (27)	66 (5)	88 (7)
Cyprinidae	0	0	0	26 (2)	0	0
Moronidae	0	0	14 (1)	13 (1)	0	25 (2)
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	14 (1)	26 (2)	13 (1)	25 (2)
Total	**13 (1)**	**152 (11)**	**278 (20)**	**450 (34)**	**172 (13)**	**176 (14)**
24-hr Total	**165 (12)**		**728 (54)**		**348 (27)**	

Table 10. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation **downstream of Watts Bar Dam** (TRM 528.0) during three weeks in May 2010. Densities derived using combined numbers of eggs or larvae and volumes sampled from all five stations along the reservoir transect downstream of the dam. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Downstream of Dam (Combined)	**Week 1 (May 11-12) Normal Generation**		**Week 2 (May 19-21) No Generation**		**Week 3 (May 25-27) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Clupeidae	3 (1)	0	0	0	0	0
Sciaenidae	0	0	0	31 (10)	8 (3)	197 (81)
Total	**3 (1)**	**0**	**0**	**31 (10)**	**8 (3)**	**197 (81)**
Fish Larvae						
Atherinopsidae	0	0	5 (2)	9 (3)	0	0
Centrarchidae	3 (1)	3 (1)	11 (4)	21 (7)	62 (24)	37 (15)
Clupeidae	207 (82)	939 (355)	279 (104)	1703 (556)	176 (68)	568 (233)
Cyprinidae	0	0	0	6 (2)	0	0
Moronidae	3 (1)	3 (1)	8 (3)	31 (10)	0	32 (13)
Percidae	0	0	0	3 (1)	0	0
Sciaenidae	0	0	3 (1)	15 (5)	13 (5)	32 (13)
Total	**216 (85)**	**945 (357)**	**306 (114)**	**1819 (594)**	**259 (100)**	**866 (355)**
24-hr Total	**1161 (442)**		**2125 (708)**		**1125 (455)**	

Table 11. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation **upstream of Watts Bar Dam** (TRM 530.2) during three weeks in August 2010. Densities were derived using combined numbers of eggs or larvae and volumes sampled from all five stations along the reservoir transect upstream of the dam. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Watts Bar Forebay	**Week 1 (Aug 17-18) Normal Generation**		**Week 2 (Aug 25-27) No Generation**		**Week 3 (Aug 30-31) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	3 (1)	0	0	0	0
Centrarchidae	13 (5)	81 (32)	10 (4)	16 (6)	3 (1)	3 (1)
Clupeidae	0	25 (10)	0	3 (1)	0	5 (2)
Cyprinidae	0	8 (3)	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**13 (5)**	**117 (46)**	**10 (4)**	**19 (7)**	**3 (1)**	**8 (3)**
24-hr Total	**130 (51)**		**29 (11)**		**11 (4)**	

Table 12. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at the **SCCW intake** (TRM529.9) during three weeks in August 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

SCCW Intake	Week 1 (Aug 17-18) Normal Generation		Week 2 (Aug 25-27) No Generation		Week 3 (Aug 30-31) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	102 (15)	13 (2)	7 (1)	0	7 (1)	7 (1)
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**102 (15)**	**13 (2)**	**7 (1)**	**0**	**7 (1)**	**7 (1)**
24-hr Total	**115 (17)**		**7 (1)**		**14 (2)**	

Table 13. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **near the right descending bank** of the Tennessee River at TRM 528.0 below Watts Bar Dam during three weeks in August 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Right Bank	Week 1 (Aug 17-18) Normal Generation		Week 2 (Aug 25-27) No Generation		Week 3 (Aug 30-31) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	0	0	0	0	0	12 (1)
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**12 (1)**
24-hr Total	**0**		**0**		**12 (1)**	

Table 14. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **40% of reservoir width from right descending bank** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in August 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

40% Right Bank	Week 1 (Aug 17-18) Normal Generation		Week 2 (Aug 25-27) No Generation		Week 3 (Aug 30-31) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	0	0	0	0	0	0
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
24-hr Total	**0**		**0**		**0**	

Table 15. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **60% of reservoir width from right descending bank** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in August 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

60 % Right bank	**Week 1 (Aug 17-18) Normal Generation**		**Week 2 (Aug 25-27) No Generation**		**Week 3 (Aug 30-31) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	13 (1)	0	0	0	0	0
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**13 (1)**	**0**	**0**	**0**	**0**	**0**
24-hr Total	**13 (1)**		**0**		**0**	

Table 16. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation at a location **near the left descending bank** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in August 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Left bank	Week 1 (Aug 17-18) Normal Generation		Week 2 (Aug 25-27) No Generation		Week 3 (Aug 30-31) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	12 (1)
Total	**0**	**0**	**0**	**0**	**0**	**12 (1)**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	0	0	0	0	28 (2)	0
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**28 (2)**	**12 (1)**
24-hr Total	**0**		**0**		**40 (3)**	

Table 17. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation in samples near **bottom of the main channel** of the Tennessee River at TRM 528.0 downstream of Watts Bar Dam during three weeks in August 2010. Numbers in parentheses represent actual numbers of eggs or larvae collected.

Near Bottom	Week 1 (Aug 17-18) Normal Generation		Week 2 (Aug 25-27) No Generation		Week 3 (Aug 30-31) Normal Generation	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Fish larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	0	0	0	0	0	0
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
24-hr Total	**0**		**0**		**0**	

Table 18. Densities (number per 1000 m^3) of fish eggs and larvae by family collected during normal and no generation **downstream of Watts Bar Dam** (TRM 528.0) during three weeks in August 2010. Densities were derived using combined numbers of eggs or larvae and volumes sampled from all five stations along the reservoir transect downstream of the dam. Numbers in parentheses represent actual numbers of eggs and larvae collected.

Downstream of Dam (Combined)	**Week 1 (Aug 17-18) Normal Generation**		**Week 2 (Aug 25-27) No Generation**		**Week 3 (Aug 30-31) Normal Generation**	
Family	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Fish Eggs						
Sciaenidae	0	0	0	0	0	2 (1)
Total	**0**	**0**	**0**	**0**	**0**	**2(1)**
Fish Larvae						
Atherinopsidae	0	0	0	0	0	0
Centrarchidae	3 (1)	0	0	0	8 (2)	0
Clupeidae	0	0	0	0	0	0
Cyprinidae	0	0	0	0	0	0
Moronidae	0	0	0	0	0	0
Percidae	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0
Total	**3 (1)**	**0**	**0**	**0**	**8 (2)**	**0**
24-hr Total	**3 (1)**		**0**		**10 (3)**	